Global Temperature Report for 2020

Posted on January 13, 2021 by Robert Rohde

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Berkeley Earth, a California-based non-profit research organization, has been preparing independent analyses of global mean temperature changes since 2013. The following is our report on global mean temperature during 2020.

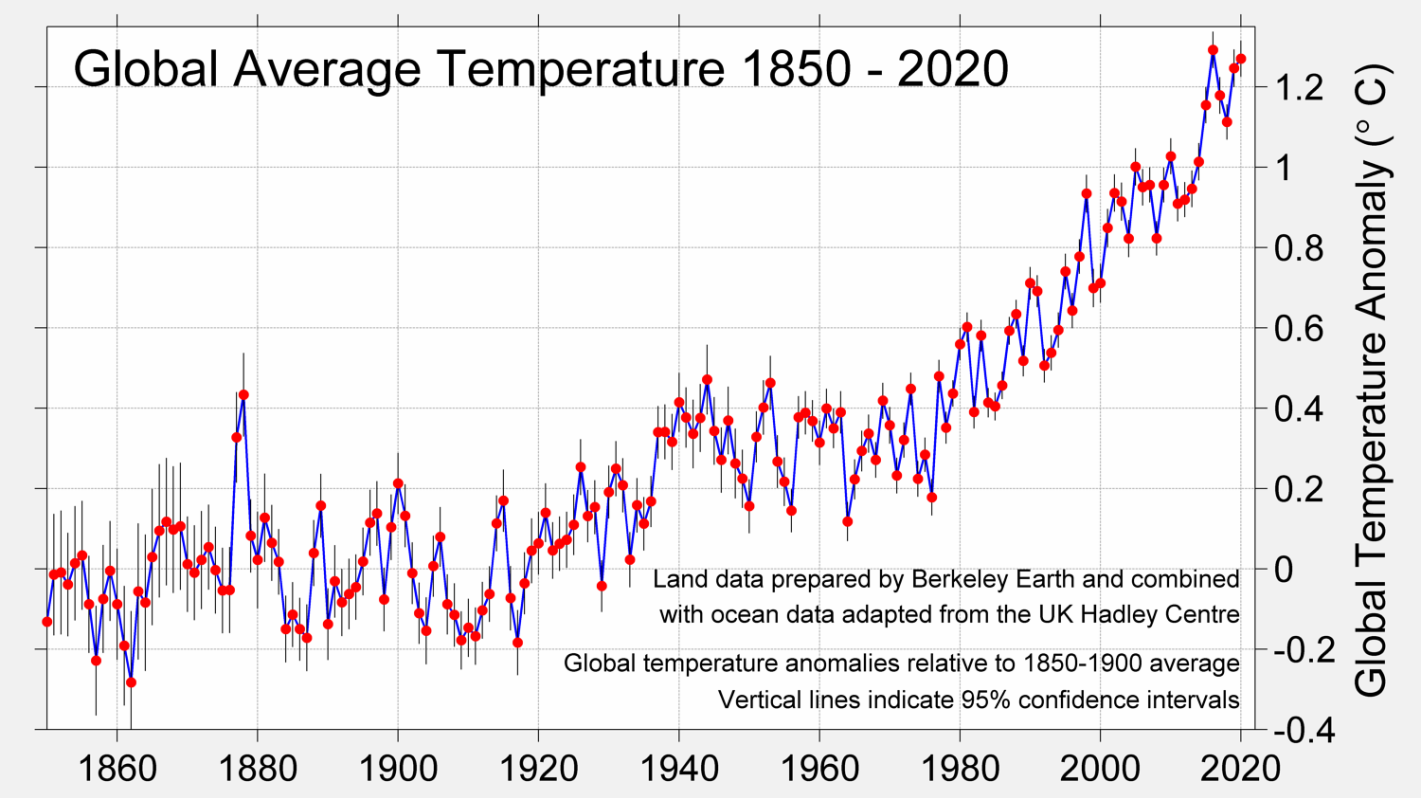
We conclude that 2020 was nominally the second warmest year on Earth since 1850. Our estimate of the global mean temperature in 2020 was slightly colder than 2016, but warmer than every other year that has been directly measured. However, the difference between 2020 and 2016 was only 0.022 °C. This is smaller than the 0.045 °C uncertainty on our ability to measure the global average temperature in 2020. This means that 2020 and 2016 could also be regarded as effectively tied.

Year-to-year rankings are likely to reflect short-term natural variability, but the overall pattern remains consistent with a long-term trend towards global warming.

In addition, 2020 was notable for:

- A new record for the warmest annual land-average of any year since 1850
- Record-shattering warmth in Siberia and Northern Asia
- The emergence of a moderate La Niña that reduced global mean temperatures in the latter half of 2020 and is likely to keep 2021 cooler than other recent years

Annual Temperature Anomaly



The global mean temperature in 2020 is estimated to have been 1.27 °C (2.29 °F) above the average temperature of the late 19th century, from 1850-1900, a period often used as a pre-industrial baseline for global temperature targets. This is ~0.02 °C cooler than in 2016, and ~0.02 °C warmer than 2019. As a result, 2020 is nominally the second warmest year to have been directly observed, though the three warmest years are all tightly clustered together relative to the uncertainty in these measurements.

This temperature in 2020 is equivalent to 0.94 °C (1.69 °F) above the 1951-1980 average which is often used as a reference period for comparing global climate analyses.

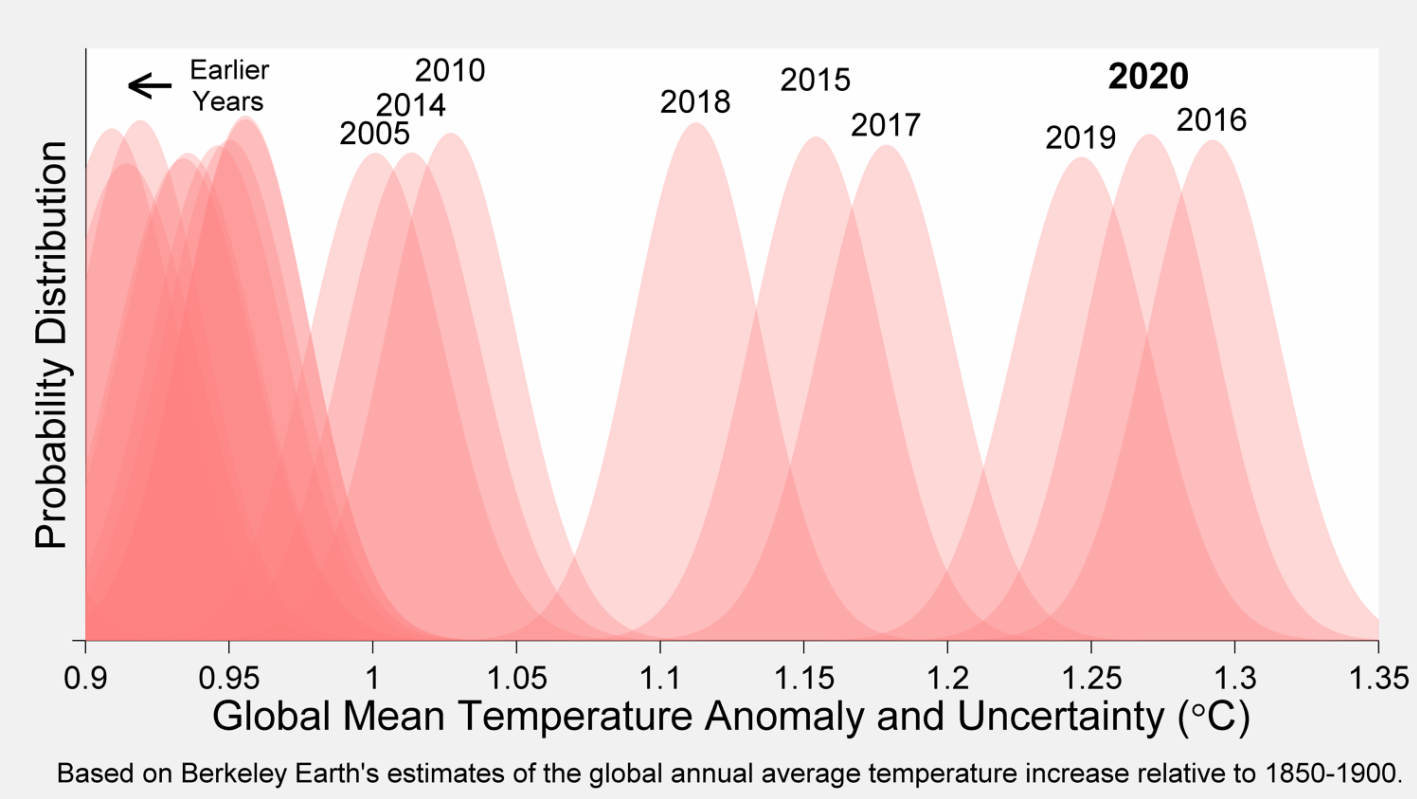
The last six years have included all of the six warmest years directly observed.

Year	Rank	Warming in °C	Warming in °F
2020	2	1.27 ± 0.04	2.29 ± 0.08
2019	3	1.25 ± 0.05	2.24 ± 0.08
2018	6	1.11 ± 0.04	2.00 ± 0.08
2017	4	1.18 ± 0.05	2.12 ± 0.08
2016	1	1.29 ± 0.05	2.33 ± 0.08
2015	5	1.15 ± 0.04	2.08 ± 0.08
2014	8	1.01 ± 0.05	1.82 ± 0.08
2013	13	0.95 ± 0.05	1.70 ± 0.08

Year	Rank	Warming in °C	Warming in °F
2012	16	0.92 ± 0.04	1.65 ± 0.08
2011	18	0.91 ± 0.04	1.64 ± 0.08
2010	7	1.03 ± 0.04	1.85 ± 0.08

Temperature change relative to the 1850 to 1900 average. Uncertainties indicate the 95% confidence range for estimating an annual temperature average, but do not include a small additional uncertainty related to the 1850-1900 average itself.

The temperature uncertainties can be visualized using the schematic below where each year's temperature estimate is represented by a distribution reflecting its uncertainty. In the analysis that Berkeley Earth conducts, the uncertainty on the mean temperature is approximately 0.05 °C (0.08 °F) for recent years. The global mean temperature in 2020 fell squarely between those observed in 2016 & 2019. The three most recent years have substantially overlapping uncertainties, leading to an associated uncertainty in the true relative rankings of these years.

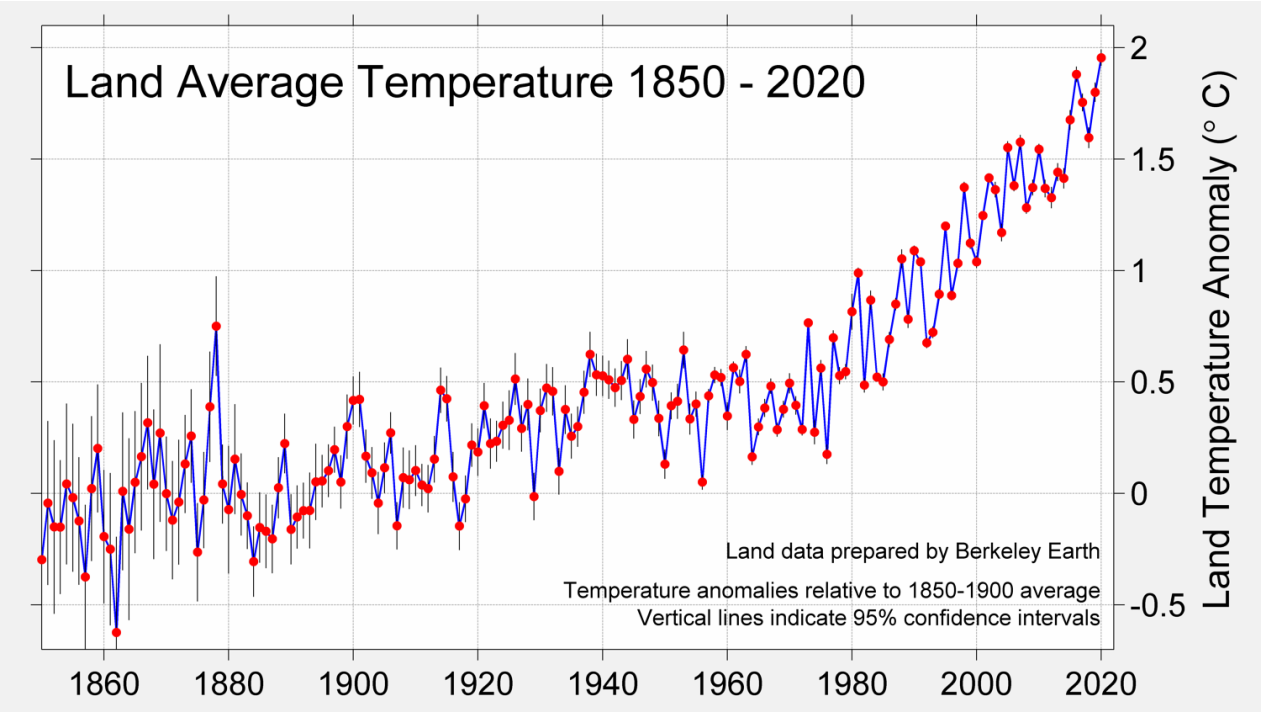


The last six years stand out as a period of significant warmth well above all previous years since 1850. This reflects the long-term trend towards global warming. Though 2020 is nominally slightly cooler than 2016, its overall temperature remains consistent with the long-term warming trend.

In addition to long-term warming, individual years are also affected by interannual variations in weather. Both 2015 and 2016 were warmed by an extreme El Niño event that peaked in Nov/Dec of 2015 and was reported by NOAA as essentially tied for the strongest El Niño ever observed. That exceptional El Niño boosted global mean temperatures in 2015 and 2016. By contrast, 2020 began with neutral conditions and finished with a moderate La Niña. This La Niña would be expected to somewhat reduce temperatures in 2020, and is likely to have a larger impact on 2021. Internal weather variability, such as El Niño and La Niña, generate year-to-year variations in temperatures that occur in addition to the long-term warming trend.

Land Average Temperature in 2020

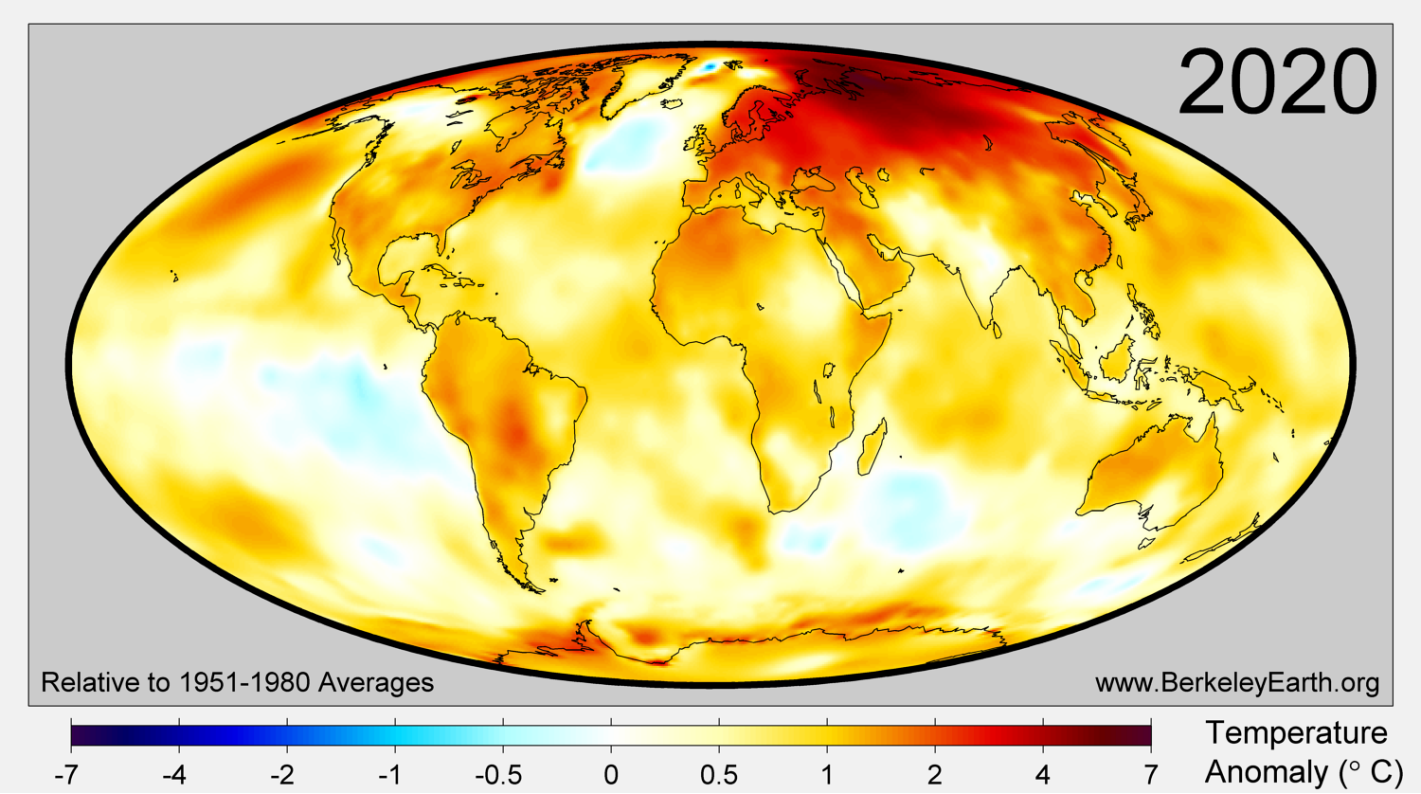
Though 2020 was nominally only the second warmest year, this was affected in significant part by the cooling effect of La Niña in the oceans. Over land, 2020 was unambiguously the warmest year that has been directly observed.



In 2020, the land average temperature was 1.96 ± 0.04 °C above the average temperature from 1850 to 1900. This unambiguously exceeds the previous record of 1.88 °C observed in 2016. As discussed below, many territories saw record warm annual averages in 2020, with conditions in Northern Asia being particularly extreme.

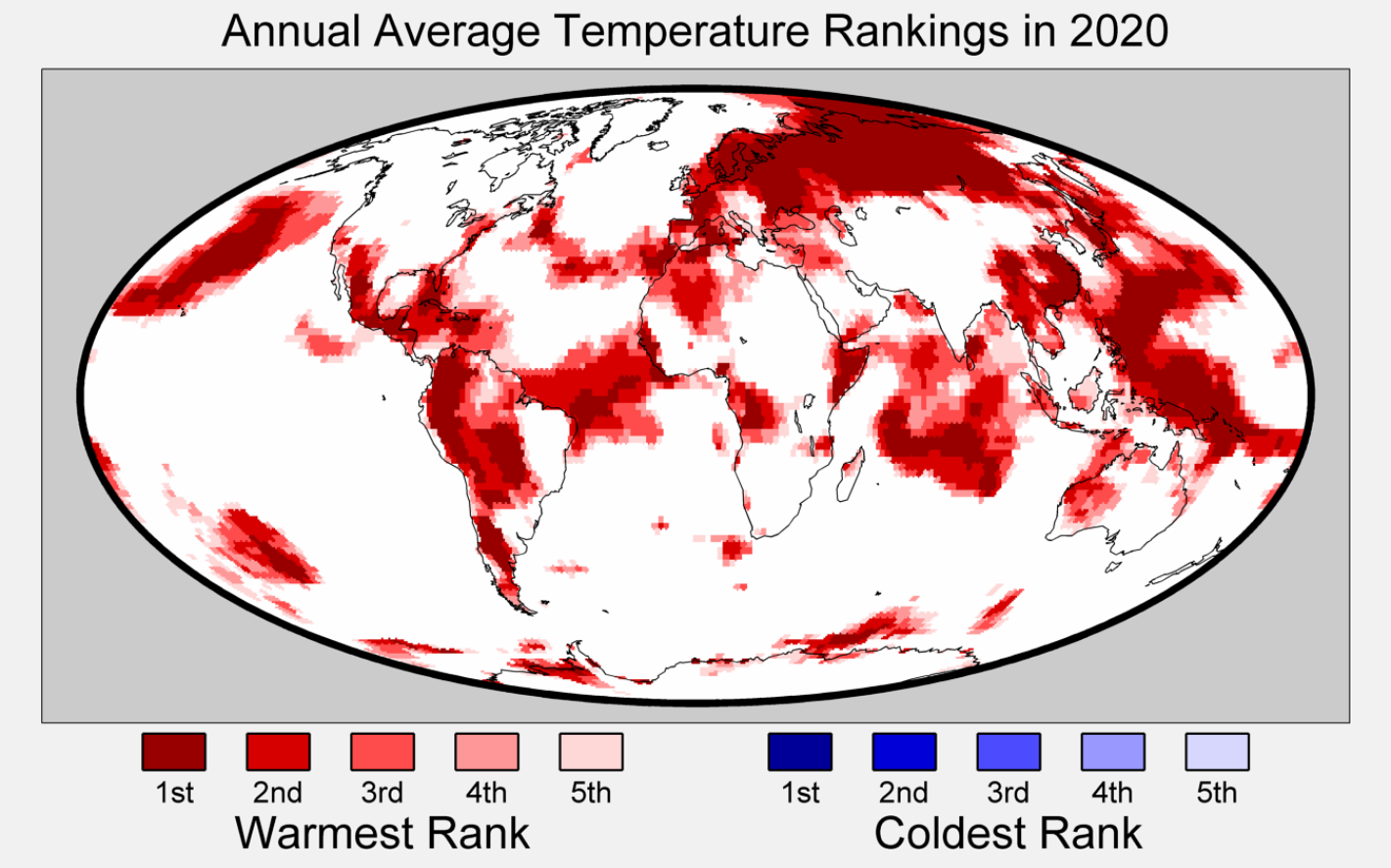
Temperature Distribution in 2020

The following map shows how local temperatures in 2020 have increased relative to the average temperature in 1951-1980.

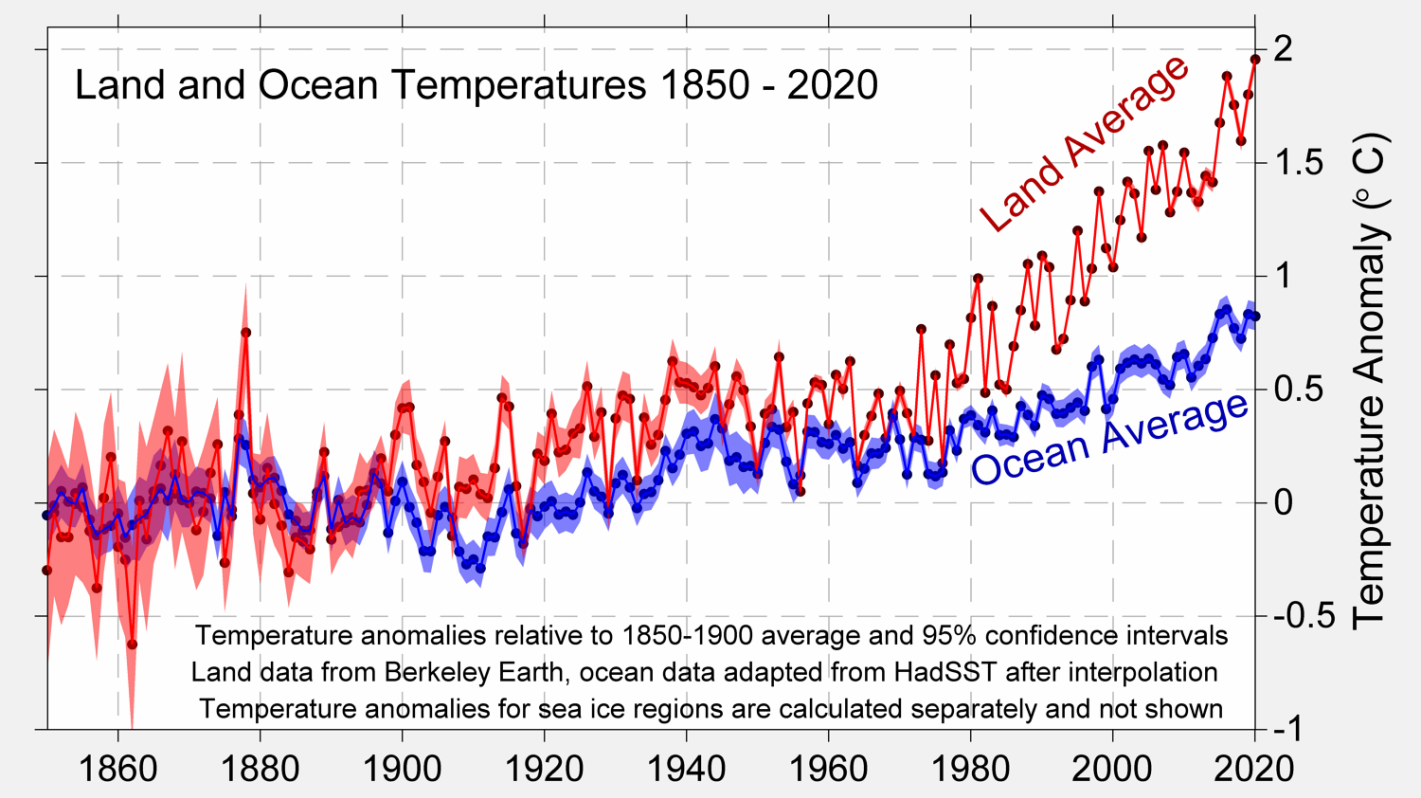


As can be expected from the global warming caused by greenhouse gases, the temperature increase over the globe is broadly distributed, affecting nearly all land and ocean areas. In 2020, 87% of the Earth's surface was significantly warmer than the average temperature during 1951-1980, 12% was of a similar temperature, and only 1.3% was significantly colder.

We estimate that 10.2% of the Earth's surface set a new local record for the warmest annual average. In 2020, no places on Earth experienced a record cold annual average.



Land areas generally show more than twice as much warming as the ocean. When compared to the 1850-1900 averages, the land average in 2020 has increased 1.96 ± 0.04 °C (3.53 ± 0.08 °F) and the ocean surface temperature, excluding sea ice regions, has increased 0.82 ± 0.06 °C (1.48 ± 0.11 °F). As already noted, 2020 was the warmest year on land. For the ocean surface, we find that 2020 nominally ranks as the 4th warmest year. However, the differences between the 1st, 2nd, 3rd and 4th warmest years in the ocean are small compared to the measurement uncertainty, meaning they are all hard to distinguish. The following figure shows land and ocean temperature changes relative to the average from 1850 to 1900. The tendency for land averages to increase more quickly than ocean averages is clearly visible.



As in other recent years, 2020 also demonstrated very strong warming over the Arctic that significantly exceeds the Earth's mean rate of warming. This is consistent with the process known as Arctic amplification. By melting sea ice and decreasing snow cover, warming in the Arctic regions causes more sunlight to be absorbed, which allows for yet more warming. 2020 was the 2nd warmest year in the Arctic.

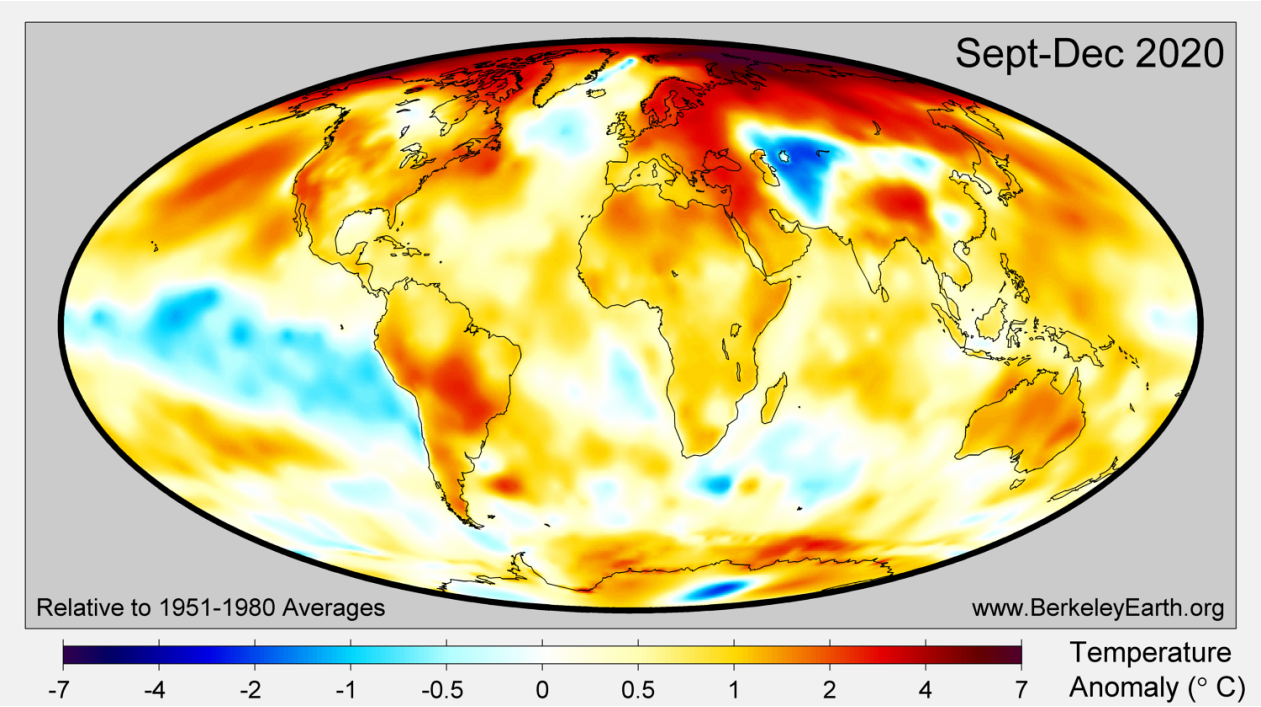
Both the tendency for land to warm faster than ocean and the higher rate of warming over the Arctic are expected based on our understanding of how increases in greenhouse gas concentrations will impact the Earth's climate. As has been reported by the Global Carbon Project and other observers, 2020 saw a new record for the level of carbon dioxide in the atmosphere. This is due to the continued accumulation of carbon dioxide from human activities. However, the annual amount of carbon dioxide emitted in 2020 was 6.7% lower than 2019 as a consequence of the COVID-19 pandemic.

Development of La Niña

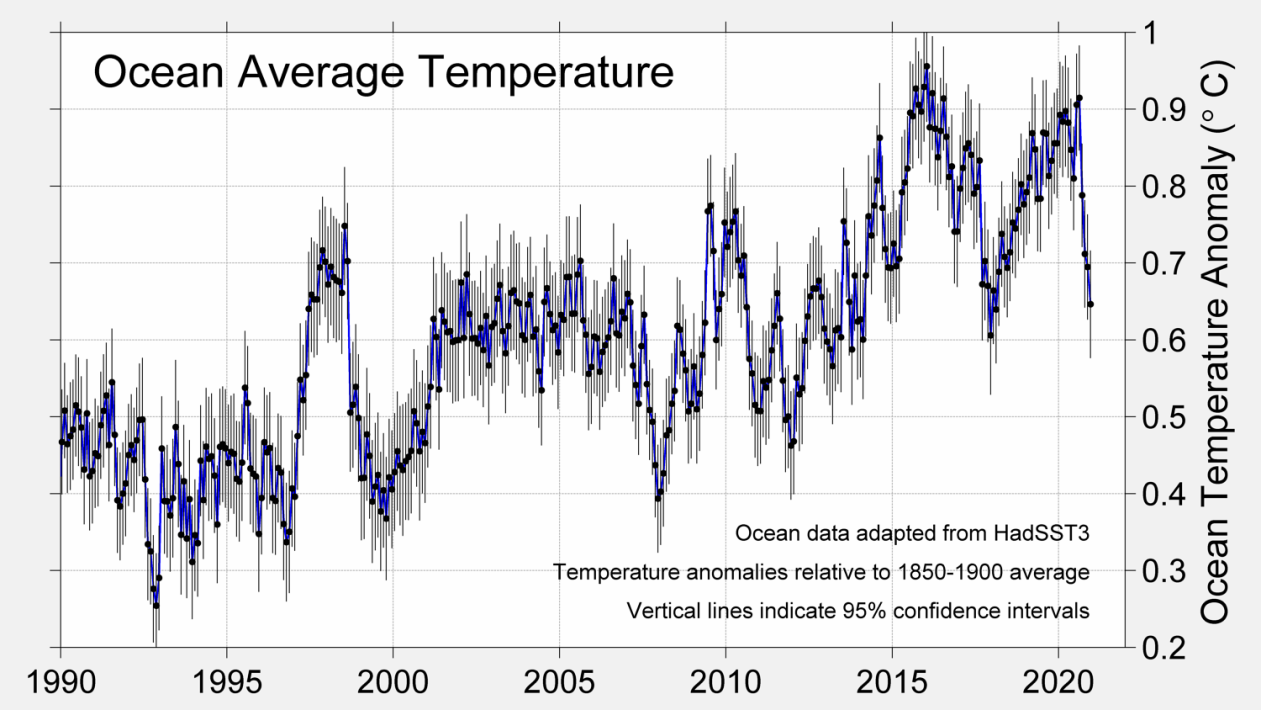
The emergence of the La Niña weather phenomenon in the latter half of 2020 had a substantial influence on temperatures in 2020, and is expected to have an even larger impact on 2021.

La Niña is characterized by the emergence of a large area of relatively cool water in the western equatorial Pacific, as can clearly be seen in this map of average temperatures from September to December. In addition to the immediate cooling in the Pacific, La Niña can have far-reaching

effects on global circulation and weather patterns. This disruption of weather patterns tends to be associated with an extended period of somewhat reduced global average temperatures that can last for months beyond the peak of the La Niña in the Pacific.



Notably, the monthly time series of ocean average temperatures has shifted sharply lower during the last four months as La Niña has developed. Without this cooling, more than 0.2 °C during the last few months, global average temperatures in 2020 would have nominally surpassed the temperatures reported in 2016.



National Average Temperature

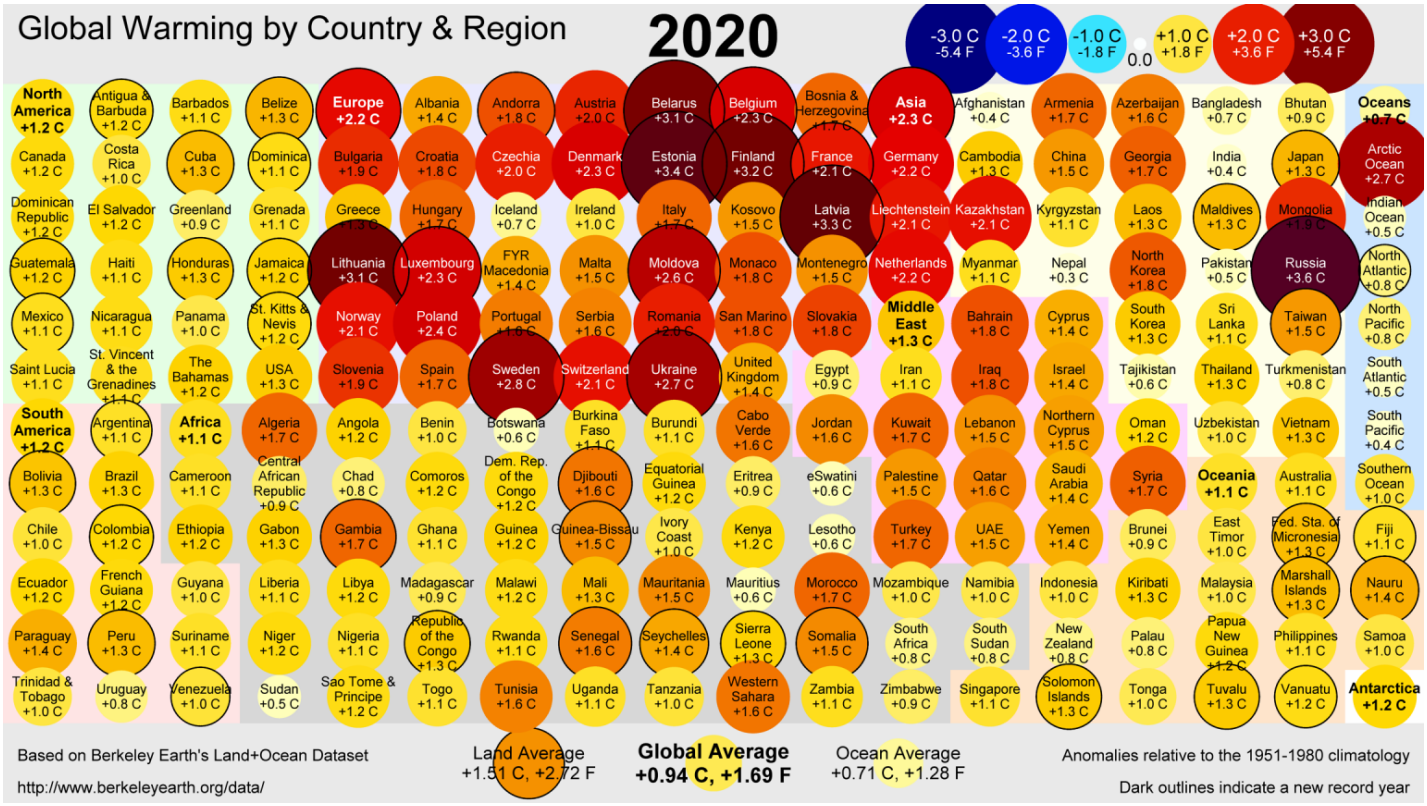
Though the focus of our work is on global and regional climate analysis, it is also possible to use our data to estimate national temperature trends.

In Berkeley Earth's estimation, 2020 had the warmest annual average since instrumental records began in the following 45 countries:

Andorra, Antigua and Barbuda, Argentina, Belarus, Belgium, Belize, Bolivia, Colombia, Cuba, Djibouti, Dominica, Estonia, Federated States of Micronesia, Fiji, Finland, France, The Gambia, Guatemala, Guinea-Bissau, Honduras, Jamaica, Japan, Latvia, Lithuania, Luxembourg, Maldives, Marshall Islands, Mexico, Moldova, Nauru, Peru, Republic of the Congo, Russia, Saint Kitts and Nevis, Senegal, Seychelles, Sierra Leone, Solomon Islands, Somalia, Sweden, Taiwan, Tuvalu, Ukraine, Vanuatu, and Venezuela

In addition, it was also the warmest year thus far observed for both the continental averages of Europe and Asia, and effectively tied for the warmest in South America.

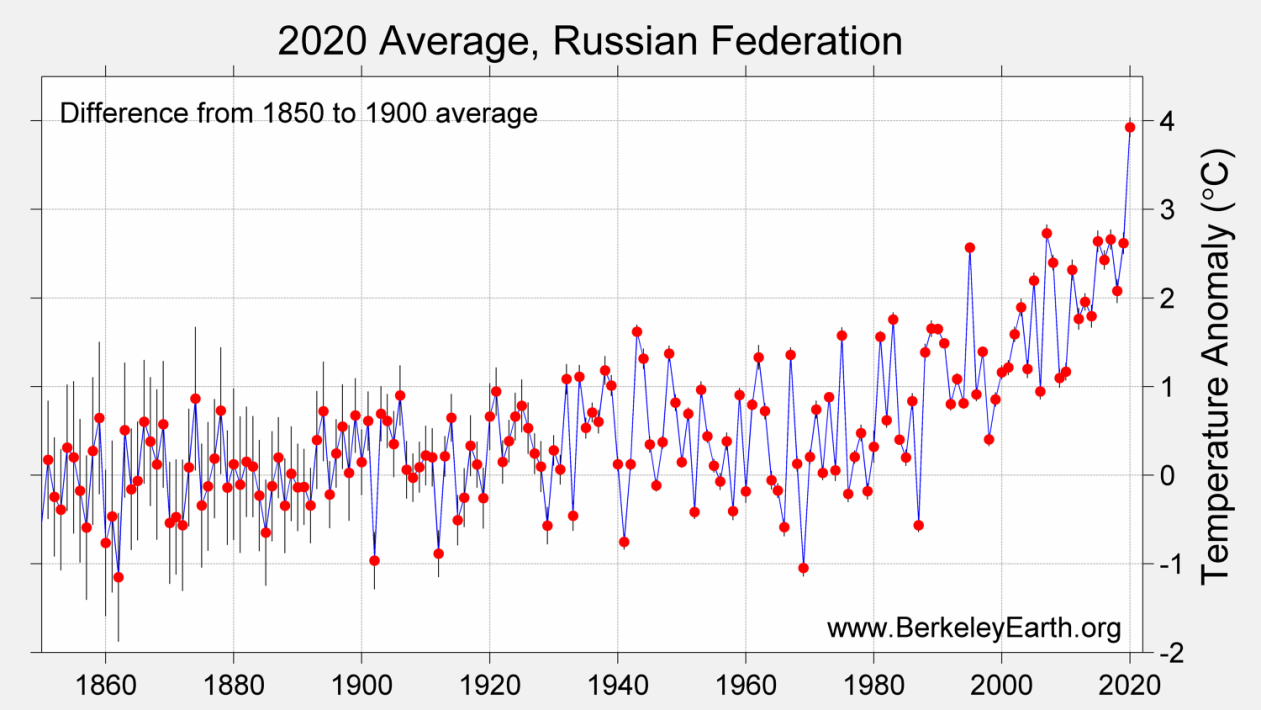
The following chart provides a summary of the warming that countries experienced in 2020 relative 1951 to 1980 averages.



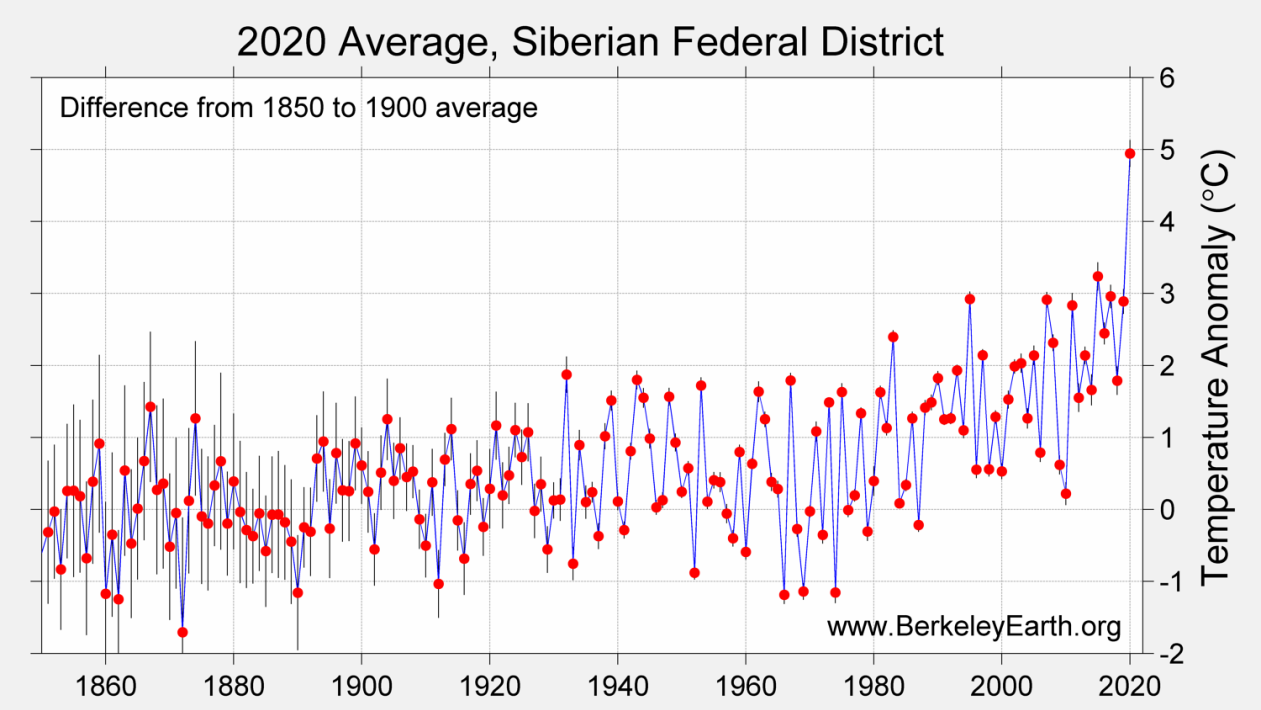
These estimates for the changes in national annual average temperatures are derived from our global temperature fields. Due to uncertainties in the analysis and the limits of our spatial resolution some national average estimates may differ slightly from the values reported by national weather agencies.

Temperatures in Russia

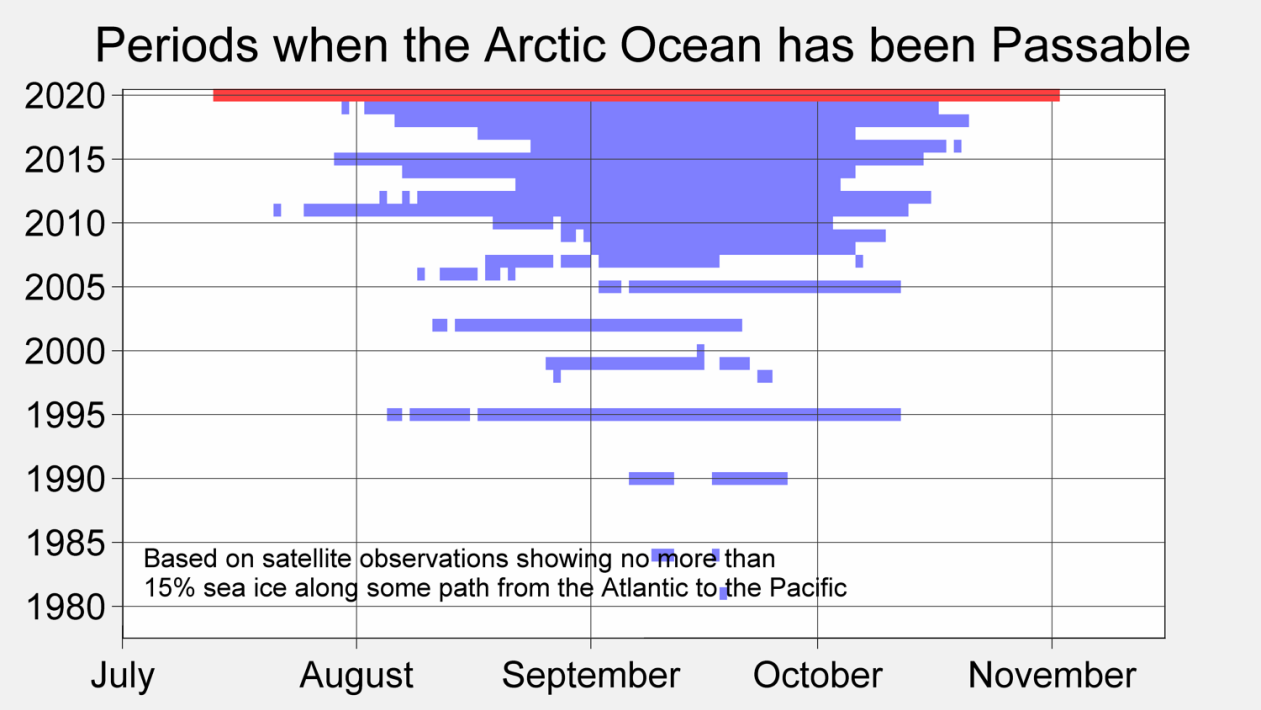
The weather conditions in Russia during 2020 were particularly extreme and worthy of extra attention. During 2020, the average temperature in Russia was nearly 4 °C (7 °F) above the pre-industrial average. This broke the previous record for warmest year in Russia by a staggering 1.2 °C (2.2 °F).



It is extremely unusual for large-scale annual-average temperature records to be broken by such a large margin. In this case, much of the effect can be associated with extraordinary warm weather patterns over Siberia. Within Russia's central Siberian Federal District, the average temperature in 2020 was nearly 5 °C (9 °F) above the pre-industrial norm, and the warmest locations in this region averaged more than 7 °C (12.5 °F) above normal.



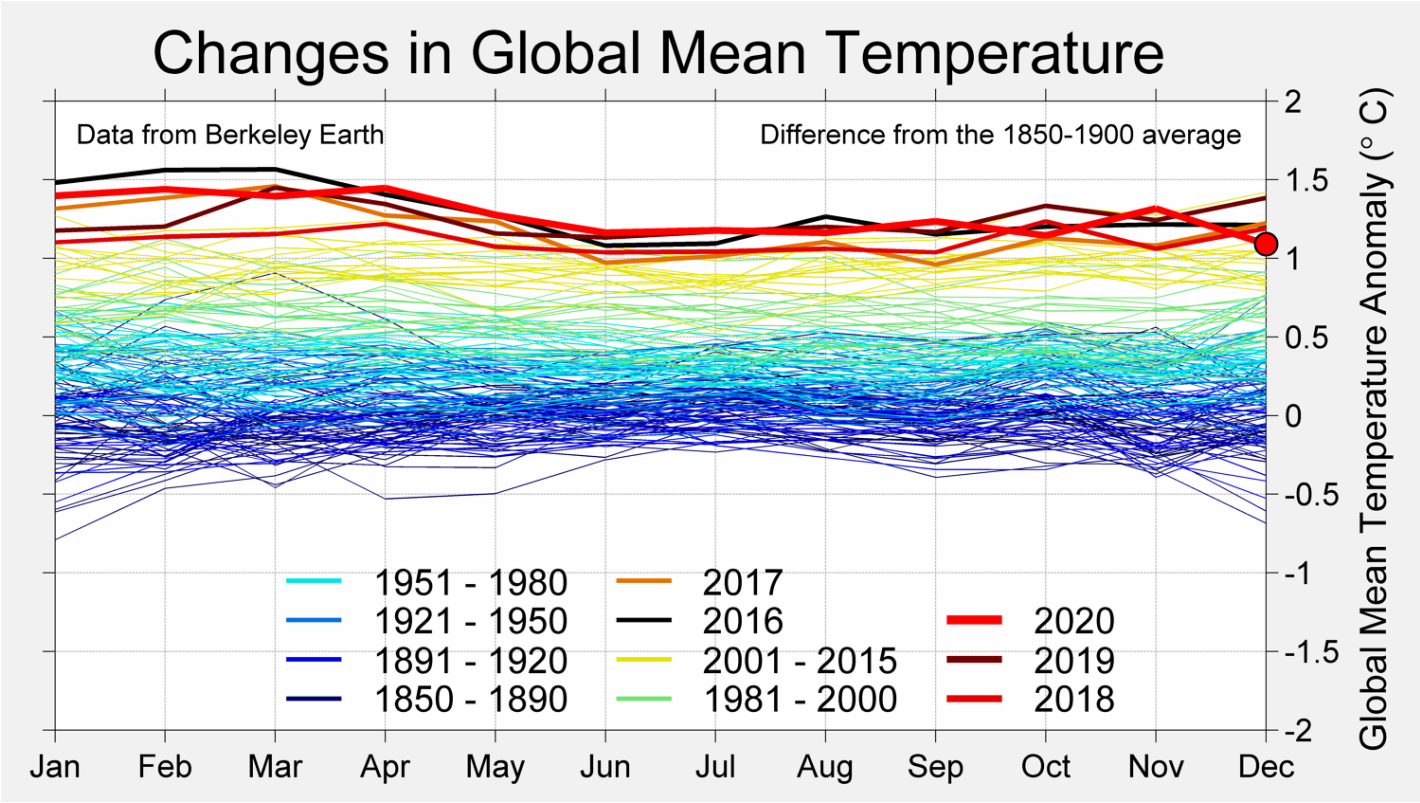
The extraordinary warmth in Siberia led to permafrost thawing and caused unanticipated disruptions. With anomalous warmth extending into the areas of the Arctic Ocean adjacent to Siberia, it also led to a record-smashing three and a half months of traversable open ocean along the Northern Sea Route (Northeast Passage) within the Arctic. Prior to the year 2005, open ocean passages in the Arctic rarely formed.

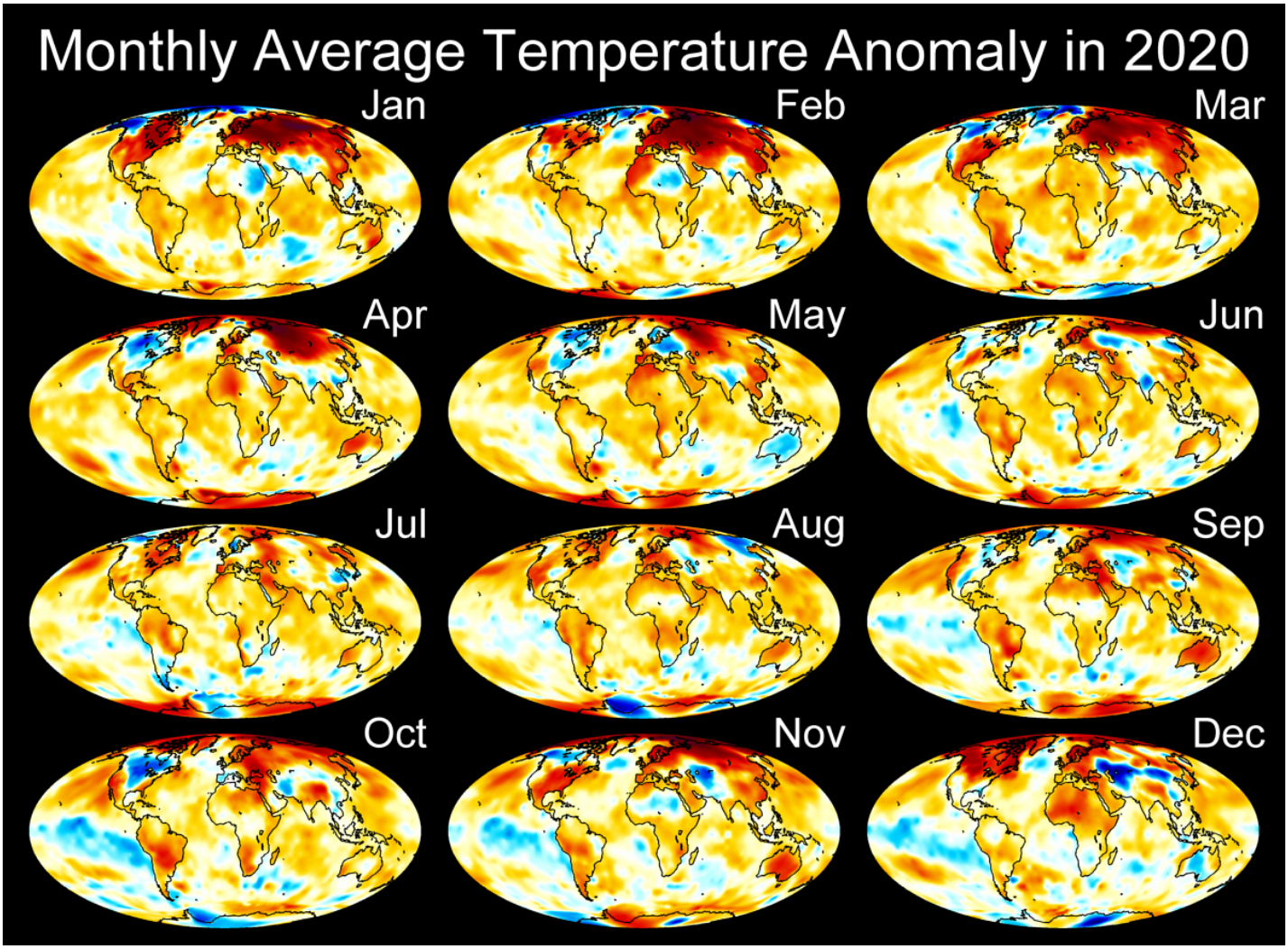


These effects are related to the phenomenon known as Arctic Amplification, whereby changes in snow and sea ice cover cause the Arctic to warm faster than other regions of the globe. However, even so, the weather pattern observed in 2020 was more severe than generally expected. The level of warmth observed this year in Siberia is not expected to become common until the latter half of the century.

Monthly Temperature Patterns

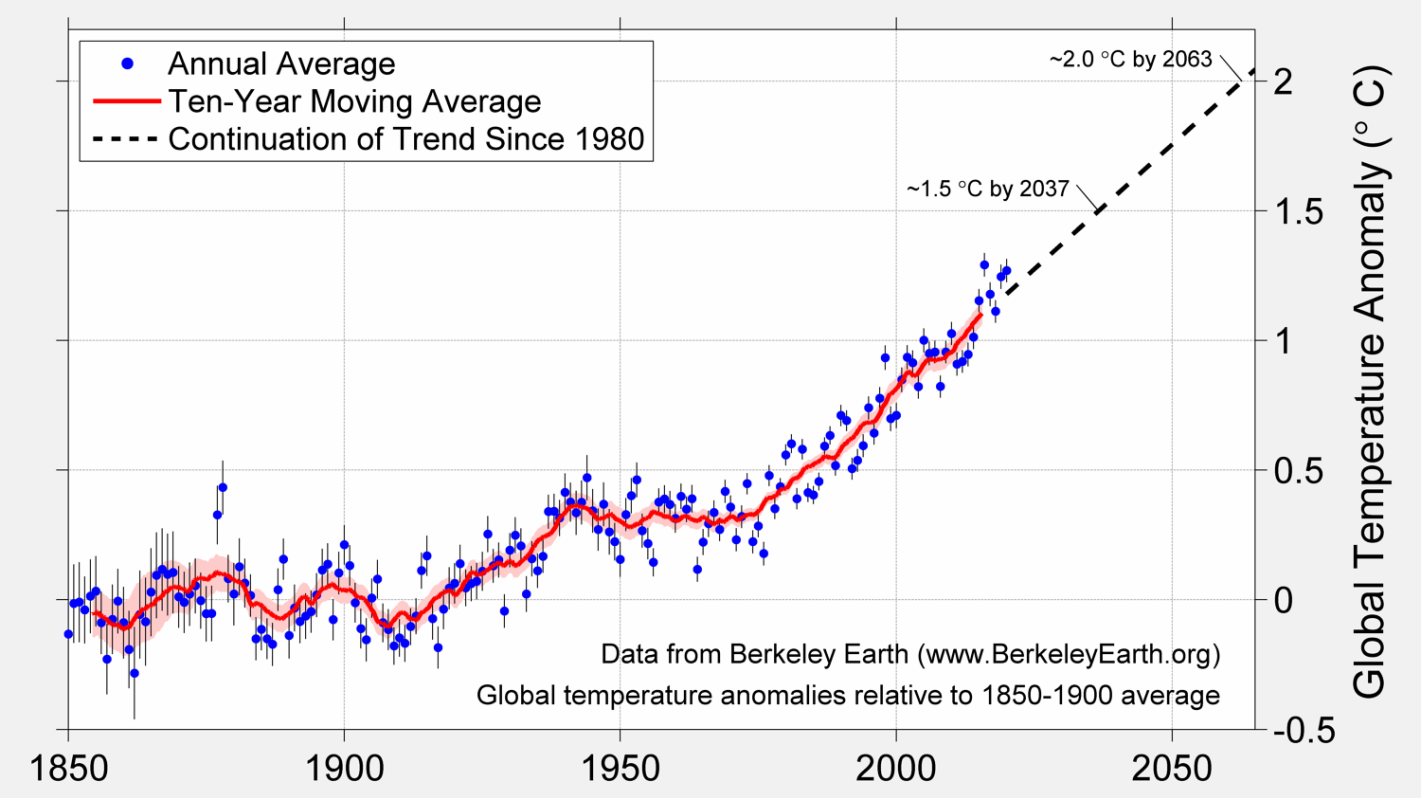
Every month in 2020 was at least 1.05 °C (1.9 °F) warmer than the 1850 to 1900 average. Six months (April, May, June, July, September, and November) set a new monthly record for the globe. Prior to October, no month ranked lower than 4th; however, October ranked 5th and December ranked 7th. These low rankings in October and December are partially due to cooling associated with La Niña.


Changes in Global Mean Temperature
Data from Berkeley Earth
Difference from the 1850-1900 average
Global Mean Temperature Anomaly (° C)
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
1951 - 1980
1921 - 1950
1891 - 1920
1850 - 1890
2017
2016
2001 - 2015
1981 - 2000
2020
2019
2018



Long-term Trend

Though it is interesting to understand the characteristics of individual years, global warming is ultimately about the long-term evolution of Earth's climate. The following chart shows a ten- year moving average of the Earth's surface temperature, plotted relative to the average temperature from 1850-1900.



Since 1980, the overall trend is +0.19 °C/decade (+0.34 °F/decade) and has changed little during this period. By continuing this trend, we can make a rough guess of how the near-future climate may develop if the forces driving global warming continue at their present rate.

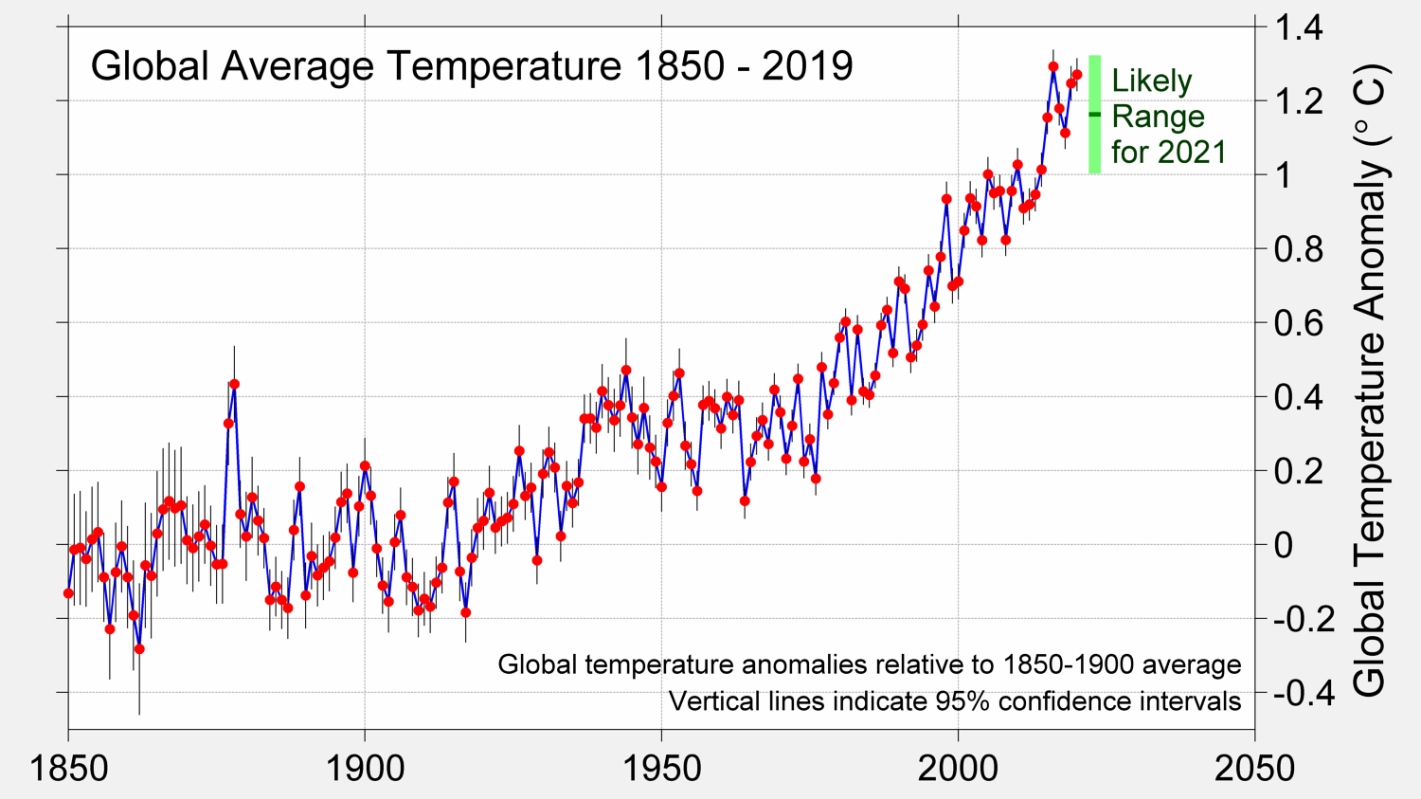
As shown in the chart, several recent years have had temperatures more than 1 °C (1.8 °F) above the average temperature from 1850-1900, often used as an estimate of the pre-industrial climate. The Paris Agreement on Climate Change aims to keep global temperature rise to well below 2 °C (3.6 °F) and encourages parties to strive for warming of no more than 1.5 °C (2.7 °F). At the current rate of progression, the increase in Earth's long-term average temperature will reach 1.5 °C (2.7 °F) above the 1850-1900 average by around 2035 and 2 °C (3.6 °F) will be reached around 2065. The increasing abundance of greenhouse gases in the atmosphere due to human activities is the direct cause of this recent global warming. If the Paris Agreement's goal of no more than 2 °C (3.6 °F) warming is to be reached, significant progress towards reducing greenhouse gas emissions needs to be made soon.

Prediction for 2021

Based on historical variability and current conditions, it is possible to roughly estimate what global mean temperature might be expected in 2021. Our current estimate is that 2021 is likely to be substantially cooler than 2020. The reason for the expectation is principally due to the ongoing La Niña event. La Niña events are associated with widespread cooling in the central Pacific Ocean,

and generally depress global average temperatures for several months following their occurrence. The swings from El Niño to La Niña and back again, are the dominant source of interannual variability in the global temperature record.

It is nearly certain that 2021 will remain within the top-ten warmest years; however, there is a 50% chance that 2021 will rank no higher than 5th warmest year. There is only a remote chance (a few percent) that 2021 will be warmer than 2016. More likely, 2021 will be one of the coolest years of this decade.

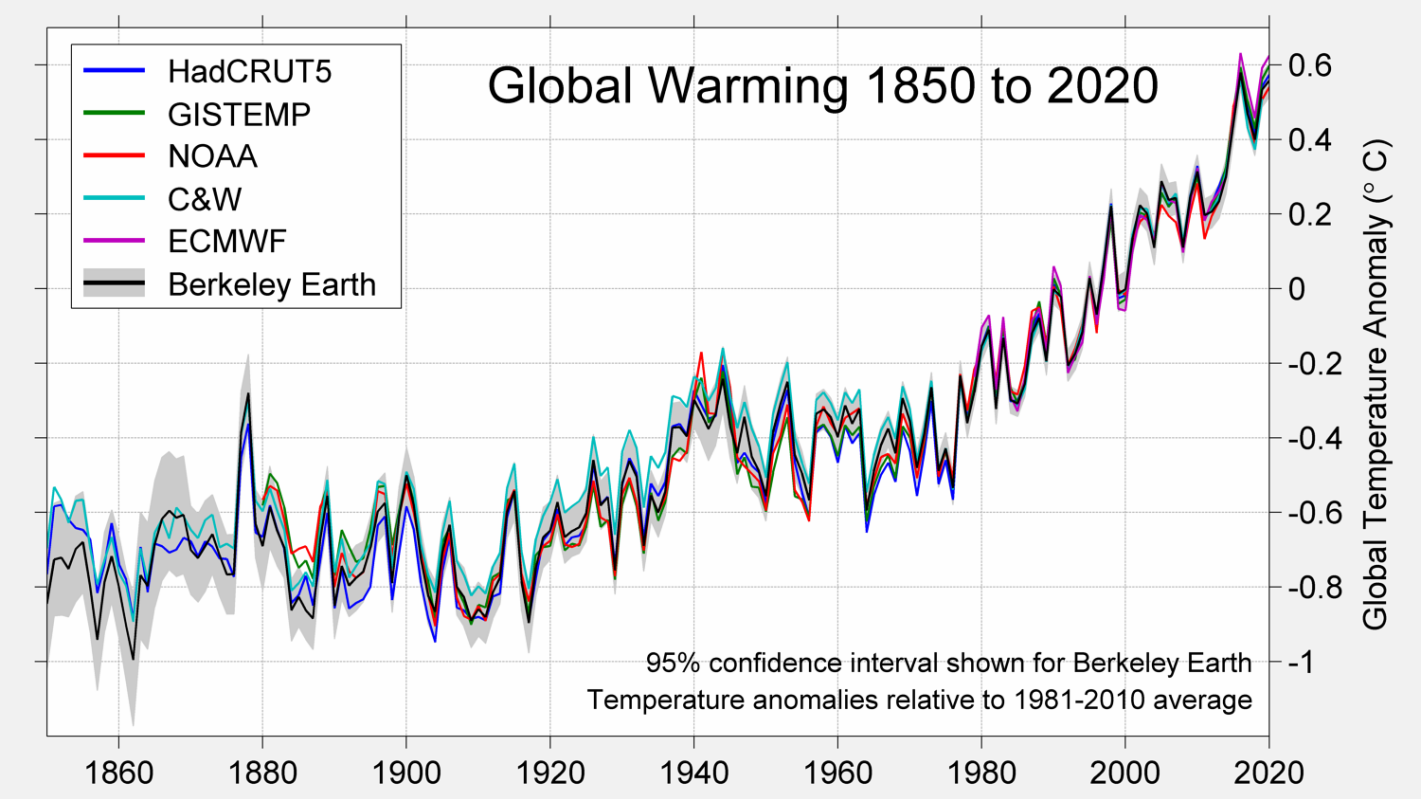


Though 2021 is expected to be relatively cool, that does not mean that global warming has stopped. Rather, it is just a minor fluctuation that may provide the world one year of slightly less exceptional weather before weather conditions swing back towards the long-term warming trend.

Comparisons with Other Groups

When preparing our year-end reports, Berkeley Earth traditionally compares our global mean temperature analysis to the results of five other groups that also report global mean surface temperature. The following chart compares Berkeley Earth's analysis of global mean temperature to that of the NASA's GISTEMP, NOAA's GlobalTemp, the UK's HadCRUT, Cowtan & Way, and ECMWF's reanalysis. All of these groups produce a similar understanding of recent climate

change. As of the time this document was being finalized, 2020 values for Cowtan & Way were not available.



Of these groups, NOAA, HadCRUT, and ECMWF concur with Berkeley Earth that 2020 was nominally the 2nd warmest year, though Berkeley Earth's margin of difference between 2016 and 2020 is actually the largest of the four. GISTEMP, places 2020 as the warmest year, exceeding 2016 by a minuscule 0.004 °C. All of the groups agree that the difference between 2016 and 2020 is within the margin of uncertainty on our ability to measure global mean temperature.

The slight disagreement in the ranking reflects both the uncertainty in these estimations and the differences in how various research programs look at the Earth. Each uses a somewhat different selection of source data and different methods of interpolation and correcting for measurement errors. Some methods are more limited than others. For example, NOAA omits most of the polar regions when estimating mean temperature changes. As a result, it is not surprising to see small disagreements among the groups.

Methodology

In reconstructing the changes in global mean temperature since 1850, Berkeley Earth has examined 21 million monthly-average temperature observations from 50,564 weather stations. Of these 19,460 stations and 198,000 monthly averages are available for 2020.

The weather station data is combined with sea surface temperature data from the UK Met Office's Hadley Centre (HadSST). This ocean data is based on 411 million measurements collected by ships and buoys, including 19 million observations obtained in 2020. We reprocess and interpolate the HadSST data to provide a more complete picture of the oceans. After combining the ocean data with our land data, we arrive at a global picture of climate change since 1850.

Uncertainties arise primarily from the incomplete spatial coverage of historical weather observations, from noise in measurement devices, and from biases introduced due to systematic changes in measurement technologies and methods. The total uncertainty is much less than the long-term changes in climate during the last 170 years.

This report is based on such weather observations as had been recorded into global archives as of early January 2021. It is common for additional observations to be added to archives after some delay. Consequently, temperature analysis calculations can be subject to revisions as new data becomes available. Such revisions are typically quite small and are considered unlikely to alter the qualitative conclusions presented in this report.

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Data

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